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PROPOSED STANDARD FOR A MICROCLIMATE COOLING SYSTEM FOR EMERGENCY RESPONDER OPERATIONS

by
Brad Laprise

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Final Report
August 2007 – December 2010

Approved for public release; distribution is unlimited

U.S. Army Natick Soldier Research, Development and Engineering Center
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14. ABSTRACT

This document is a proposed standard, developed by the Natick Soldier Research, Development and Engineering Center (NSRDEC), that identifies the relevant parameters that define the performance, physical characteristics, and interfaces of a Microclimate Cooling System (MCS), specifically for the Emergency Responder community. MCS have been shown to significantly improve mission duration, reduce the rate of body core temperature rise, and improve the thermal comfort of personnel exposed to heat stress conditions while wearing Personal Protective Equipment (PPE). There are many technologies, products, and systems available that provide a microclimate, or personal, cooling capability. However, there can be significant differences in their thermal performance levels, effectiveness, durability, safety, reliability, and compatibility with PPE. This document also defines the verification methods associated with each performance parameter and identifies the format for reporting the results of each verification event. The intent is to provide a clear means for vendors, distributors, and manufacturers to provide the necessary data and information to the Emergency Responder community on their MCS product(s), and for the Emergency Responder community to identify their cooling requirements based on the environment, PPE being worn, and work levels.

15. SUBJECT TERMS

SAFETY HUMAN BODY COOLING AND VENTILATING EQUIPMENT BODY TEMPERATURE
COOLING CAPABILITIES MICROCLIMATE COOLING SYSTEMS EMERGENCY RESPONSE
RESPONSE COMPATIBILITY MEASURES OF EFFECTIVENESS TEMPERATURE CONTROL
INTERFACES ENVIRONMENTS PERSONAL COOLING SYSTEMS PROTECTIVE CLOTHING
DURABILITY SPECIFICATIONS TC(THERMAL COMFORT) PERFORMANCE CRITERIA
STANDARDS PPE(PERSONAL PROTECTIVE EQUIPMENT) EMERGENCIES THERMOREGULATION
RELIABILITY TPP(THERMAL PROTECTIVE PERFORMANCE) HEAT STRESS(PHYSIOLOGY)

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PROPOSED STANDARD FOR A MICROCLIMATE COOLING SYSTEM FOR EMERGENCY RESPONDER OPERATIONS

This report proposes a standard for personal cooling capability technology to be used with personal protective equipment (PPE) worn by emergency responders. The research that was the basis for this proposal was performed by the Natick Soldier Research, Development and Engineering Center (NSRDEC) between August 2007 and December 2010. The Department of Homeland Security Science and Technology Directorate funded the production of the work presented in this material under IAA M42356 with NSRDEC.

For many Emergency Responder personnel across the county, exposure to high heat stress conditions during the summer months is a common occurrence. PPE is intended to provide protection against various hazards and threats; however, high insulation and low water vapor permeability characteristics of PPE can significantly inhibit metabolic heat transfer to the external environment. As a result, heat is stored, operational performance suffers, and heat injuries can occur. While a number of behavioral solutions can be taken to prevent or delay the onset of heat injury (e.g., seeking air conditioned spaces, staying hydrated, implementing work/rest cycles, staying fit, acclimating to the heat, etc.), the implementation of a personal cooling capability in the microclimate between the skin and innermost clothing layer has proven to be very effective. Microclimate Cooling Systems (MCS) have been shown to significantly improve mission duration, reduce the rate of body core temperature rise, and improve mental acuity. There are many technologies, products, and systems available that claim to provide a microclimate, or personal cooling capability. However, there can be significant differences in their thermal performance levels, effectiveness, durability, safety, reliability, and compatibility with PPE.

1. Scope

This Standard covers the metrics and verification procedures that describe the characteristics of an MCS for Emergency Responder personnel. It is comprised of a Core Document and an Addendum (included as Appendix A) that address Emergency Responder user-specific metrics.

1.1.Core Document. The Core Document includes the definition of fundamental, non-user-specific parameters that characterize the performance of an MCS. Specifically, this document includes performance based definitions, environmental criteria (e.g., mechanical shock, vibration, rain, blowing sand/dust, etc.), and safety and integration related definitions. In addition, the Core Document incorporates the verification methods required to validate the parameters. Verification methods may reference other test standards, describe specific test methods, or explain how an analysis should be conducted.

1.2 Addendum. The Addendum (Appendix A) addresses MCS metrics specific to each designated user group. It includes a verification matrix based on MCS type (see Section 4) and information on MCS cooling rate(s) as a function of environmental conditions (e.g., temperature, humidity), the PPE being worn (heat storage), and user activity levels/metabolic rates (heat generation).

Note 1 ─ As of this initial publication, the only user group for which specific PPE and metabolic rates have been defined is the U.S. Customs and Border Protection (CBP). As other user groups are identified and defined, they will be included in the Addendum (Appendix A).

2. Definitions and Terminology

- *Microclimate Cooling System (MCS):* A device or system that conditions the microclimate under PPE. In addition, for the purposes of this document, an MCS is further defined as a device that:
  - is worn by the user.
  - provides a cooling capability to not more than one user at a time.
  - does not require a user to be tethered via electrical cable, hoses, etc. to an external, non-body-worn component (e.g., air conditioner, liquid chiller, insulated container, electrical outlet, etc.).
- *Consumable:* Any MCS component that is expended and must be replaced or recharged to continue system operation.

- *Personal Protective Equipment (PPE):* Specialized clothing or equipment "designed to protect workers from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards" [1].
- *Material Safety Data Sheets (MSDS):* Standardized documents that provide information on the properties of chemicals and hazardous materials, including exposure limits, disposal procedures, precautions, health and physical hazards, etc.

3. Significance and Use

This Standard identifies the relevant parameters that define the performance, physical characteristics, and interfaces of an MCS, specifically for the Emergency Responder community. In addition, it defines the verification methods associated with each parameter and identifies the format for reporting the results of each verification event. The intent is to provide a clear means for vendors, distributors, and manufacturers to provide the necessary data and information to the Emergency Responder community on their MCS product(s).

4. Classification

4.1 Type I. A Type I MCS has all of the following characteristics when in use:

- No moving parts
- Does not require an electrical or fuel based power source
- Worn completely under PPE

4.2 Type II. A Type II MCS has one or more of the following characteristics when in use:

- Moving parts
- Uses an electrical or fuel based power source
- Partially worn external to PPE

5. Markings

Each MCS shall be marked clearly and permanently with the name of the manufacturer or supplier, classification (see Section 4), and garment sizing (e.g., "small", "medium", "large", etc.). All markings shall be made on the major MCS components, including cooling garments/vests and external body worn cooling source (e.g., blower, refrigeration device, etc.). Labels and/or markings shall be provided whenever it is a necessary for users to identify, interpret, follow procedures, or avoid hazards. Identification of user interface(s) shall be labeled. This includes, but is not limited to, air or fluid connectors, electrical power and controls connectors, switches/knobs, etc.

6. Performance

This section defines the parameters that characterize the performance of an MCS. The seller shall provide information on these parameters in accordance with the data sheet in Appendix B. Note that there may be some variability in the required parameters, depending on the mission requirements of specific users. An Addendum is provided in Appendix A, which specifies the parameters that must be verified based upon the Emergency Responder user group.

6.1 Thermal Performance.

The thermal performance of an MCS is defined as the net amount of heat removed from a human. This is further defined as the heat loss measured after the passive evaporative potential has been considered - this is largely a function of the water vapor resistance characteristics of the outer PPE worn over the MCS. Since human testing is beyond the scope of this standard, the actual or net thermal performance of an MCS is determined by subtracting the evaporative potential from the total heat removed from a thermal heated manikin when measured in accordance with ASTM F2371-05 *Standard Test Method for Measuring the Heat Removal Rate of Personal Cooling Systems Using a Sweating Heated Manikin* [2]. The outer PPE has a significant effect on the thermal performance of an MCS. Conduct testing using the PPE listed in Appendix A.

The seller is responsible for obtaining the appropriate PPE and securing a test facility to conduct the required testing.

The MCS must be capable of operating at full thermal performance levels as users engage in typical movements, including the prone position. Therefore, the MCS shall be capable of providing the thermal performance as tested in accordance with the procedures in ASTM F2371-05, independent of its orientation with respect to gravity. Due to the limitations of the thermal performance test procedure, this requirement shall be validated through analysis, which should show the extent to which the MCS meets this requirement at orientations around each of the axes as shown in Figure 1.

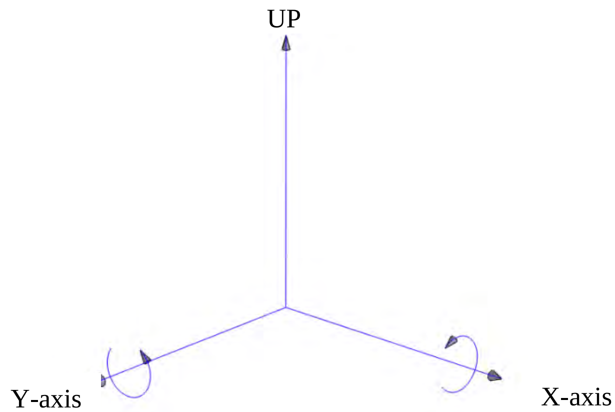

Figure 1. Axes Designations

Test data reporting shall include the following:

- Name of test facility
- Date of testing
- PPE configuration tested; includes a list of the clothing layers and description of how the MCS was integrated into the PPE.
  Note 2 — Users should compare vendor net cooling data with the cooling rate recommendations in Appendix A.
- Average net heat removal rate in watts (in accordance with ASTM F2371 [2], report only the data that are at least 50 W above the baseline (evaporative potential))
  Note 3 — If any consumables are replaced during testing, report the additional cooling duration provided.
- Duration of net heat removal rate in minutes (in accordance with ASTM F2371 [2], report only the period of time during which the net heat removal rate is at least 50 W above the baseline (evaporative potential)).
- Through analysis, show the extent to which the MCS is capable of maintaining its thermal performance in the orientations described in Section 6.1.

See MCS data sheet in Appendix B for reporting format.

6.2 Weight

6.2.1 System Weight. Report the weight, in pounds, of the MCS as tested in Section 6.1. Weight includes the complete system as worn by an individual (includes electrical cables, tubing, power source, etc.) to provide the net cooling measured in Section 6.1. Support equipment (e.g., battery chargers, insulated storage containers, freezers) should not be included.

6.2.2 Consumable Weight. If applicable, report the weight of any consumable item that must be replaced to extend the MCS performance beyond the duration measured in Section 6.1. These include, but are not limited to batteries, fuel, phase change material (e.g., ice), water, desiccant, chemicals, etc. They do not include items that must periodically be replaced for maintenance reasons.

See MCS data sheet in Appendix B for reporting format.

6.3 Volume/Bulk/Dimensions

6.3.1 System Dimensions. For Type II MCS, report the volume (cubic inches) of the MCS or major components of the MCS in its operational condition for which dimensions (inches) can be measured. Examples of major

components include refrigeration devices, ice bottles, cables, tubing, pouches. Support equipment (e.g., extra batteries, battery chargers, insulated storage containers, freezers) should not be included.

6.3.2 System Bulk. For Type I MCS or components of Type II MCS that are intended to be worn completely under PPE for which dimensions are not easily measured (e.g., ice or phase change vest, tube-type cooling garment), report the bulk of the item in its operational condition by qualitatively describing the body surface area covered (e.g., torso, arms, legs) and the depth or thickness (inches) of the item.

See MCS data sheet in Appendix B for reporting format.

6.4 Noise

6.4.1 Hearing Loss Prevention. The time of safe exposure to the output level of a Type II MCS can be determined through the use of Table 1-1 at the following link: http://www.cdc.gov/niosh/docs/98-126/chap1.html [3]. System assessment and medical surveillance criteria are also provided at this reference. The output intensity shall be measured using a sound level meter at approximately 1 m from the MCS. Intensity shall be measured in dBA and reported on the MCS data sheet (Appendix B).

6.4.2 Aural Non-Detectability. Aural detection is a function of background noise, terrain, ambient conditions, and the threshold of hearing. Non-detectability can be defined as the distance at which an acoustic source can no longer be heard.

6.4.2.1 Acoustic Detection Test Method. Take sound measurements at every 15° around the MCS in an anechoic chamber. The sound measurement system should consist of one or more laboratory quality microphones with a frequency response from 2 to 20 kHz. The microphones should be set at least 1 m from the equipment in a level plane with the equipment. The waveforms shall be recorded, and a one-third octave analysis shall be performed in accordance with ANSI S1-1-1986, S*pecifications for Octave –Band and Fractional-Octave-Band Analog and Digital Filters* [4]. Record the background noise, temperature, and humidity at the time of measurement. The resulting noise spectra can be used in a detection model (see Section 6.4.2.2) for predicting non-detectability ranges. Note that the seller is responsible for securing a test facility to conduct the required testing.

6.4.2.2 Acoustic Detection Modeling. Enter the measured data into the Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED) Auditory Detection Model or equivalent commercial model. Execute the model to determine the detection envelope and associated frequencies at which the MCS is aurally detected under the conditions cited in the Addendum (Appendix A) for each specific user group. Report the greatest detection range on the MCS data sheet (Appendix B).

Note 4 ─ A copy of the Auditory Detection Model and instructions on its use may be obtained from the Natick Soldier Research, Development and Engineering Center (NSRDEC).

See MCS data sheet in Appendix B for reporting format.

6.5 Controls

Report the extent to which the MCS provides a user capability to control the functionality and operation of the cooling rate. Examples include an on/off switch or a multiple position switch to control fan speed on an ambient air blower system. Note that an MCS shall include sufficient safeguards to avoid inadvertent activation/ deactivation. An example of MCS that may not feature an on/off or control capability is ice or phase change material vests, which should be entered as "N/A" on the MCS data sheet (Appendix B).

See MCS data sheet in Appendix B for reporting format.

6.6 Energy Source

The MCS energy source is defined as the component that provides energy to operate a Type II MCS during use.

The MCS energy source does not include motors, engines, etc. that *convert* the energy into motion, heat, etc.

The MCS energy source does not include the source required to operate support equipment, such as freezers, battery chargers, regenerators, etc.

Report the specific energy source used to power the MCS. Reporting should include the type of energy source (e.g., battery, fuel, etc.) and the "quantity" or "amount" needed to provide the net cooling measured in Section 6.1.

See MCS data sheet in Appendix B for reporting format.

6.7 Support Equipment.

Report all of the support equipment that a user would need to recharge or store the MCS consumables reported in Section 6.2.2. Support equipment includes, but is not limited to, battery chargers, insulated storage containers, freezers, etc.

See MCS data sheet in Appendix B for reporting format.

6.8 PPE Integration.

The use of an MCS shall not compromise the fit or functionality (i.e., protection capabilities) of the PPE with which it is worn. Refer to the Addendum to this Standard (Appendix A) for general guidance on the PPE worn by specific Emergency Responder user groups. Any test data or analysis information that shows that the fit and functionality of specific PPE has not been compromised when worn or used in conjunction with the MCS shall be entered on the MCS data sheet (Appendix B).

6.9 MCS Safety and Health Hazards

6.9.1 Sharp Edges. The MCS shall not have any sharp edges or pointed corners that could potentially cause an injury to users during operation and/or maintenance activities.

6.9.2 Snag Hazards. The MCS design shall guard against components that might contribute to hazards from snags that interfere with the user's ability to move freely.

6.9.3 Touch Temperature. During operation, the MCS shall not present a contact burn hazard to users in close proximity or in direct contact with the MCS. MCS surface temperatures for all components/items where there is a potential for continuous contact with bare skin shall not exceed 113 °F; the minimum temperature shall not be below 39 °F.

6.9.4 Moving Parts. The MCS shall provide protection (e.g., physical guards) to users from moving parts and components within the MCS.

6.9.5 Energy Source. Compartments containing the MCS energy source (e.g., battery housing) must keep the energy source dry if it is necessary for the source to be dry to maintain operability and long-term survivability as a power source.

6.9.6 Material Safety Data Sheets (MSDS). MCS vendors shall provide an MSDS for MCS components and materials in accordance with Federal, state, and local laws and regulations. Report a list of the MSDSs submitted on the MCS data sheet (Appendix B).

6.9.7 Electrical. The MCS shall include short circuit protection to guard against electrical shock, circuit damage, overheating, fire, or explosion. If applicable, MCS vendors shall provide a certificate of compliance, which specifically cites the type of hazardous location(s) for which their product has been certified as "intrinsically safe".

6.9.8 Materials. Health hazards associated with the MCS shall be eliminated or reduced to acceptable levels. Hazards associated with toxic, allergenic, or combustible materials must be identified and reduced through design and selection of materials. Hazardous material exposure to personnel shall be controlled to levels below the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (http://www.osha.gov/SLTC/pel/) [5]. The MCS must not present any uncontrolled health hazard throughout the life cycle of the item and shall be constructed of materials that are non-toxic when in contact with the skin and open wounds.

6.10 Human Factors Engineering

6.10.1 Quick Release. Type II MCS must provide a quick release functionality to facilitate an emergency doff capability. The quick release shall allow the MCS components worn external to PPE to be physically separated from the user's body and disconnected from the MCS component(s) worn under PPE.

6.10.1.1 Connectors. All connectors in Type II MCS (e.g., electrical or fluid) must have a hands-free disconnect capability. The in-line breaking force required to separate the connectors, as a system, shall be no less than 8 lbf and no greater than 12 lbf. Connectors shall be tested as a system, using mechanical testing equipment and a constant rate of extension process. Alternatively, break force may be determined by securing one-half of the connector(s) to a fixed point and applying a load (e.g., incremental weights) to the mating connectors. Report the average break force for each MCS connector (minimum of 10 connect/disconnect cycles) in Appendix B.

6.10.1.2 Emergency Doff. Type II MCS components worn external to PPE must be capable of being doffed quickly. Report the average MCS doff time on the MCS data sheet (Appendix B) based upon a minimum of three tests. Use at least one of the PPE configurations listed in Appendix A.

6.10.2 Sizing. The MCS shall be available in a sufficient number of sizes to accommodate a wide range of male and female body sizes. Adjustability within a size is desired to allow for optimal fit. General guidance in determining the user population's fit criteria may be obtained from US Army standards as follows: the MCS shall comfortably and effectively fit the central 90% of the male and female USA (or military) population for chest circumference and any other body dimension(s) that are critical to item fit and function (NATICK/TR-89/044, *Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics* [6]). Report the size, body area parameter (e.g., chest circumference) and dimensional range, as shown in Appendix B.

See MCS data sheet in Appendix B for reporting format.

6.11 Launderability

Any textile based MCS component shall be capable of being laundered using common washing/drying procedures (vendor choice). The vendor shall supply laundering instructions with the MCS. A short description of the laundry procedures shall be entered on the MCS data sheet (Appendix B).

See MCS data sheet in Appendix B for reporting format.

6.12 Environmental Performance

Exposure to environmental stresses may impact the functionality, durability, and reliability of an MCS. Exposures may occur during operational missions and/or when stored or transported. The extent to which an MCS is exposed to the many types of environmental effects is highly dependent on where and how it is used. This section defines various environmental parameters against which an MCS shall be assessed. After each environmental verification event, a thermal performance test (see Section 6.1) shall be conducted to confirm that the MCS cooling capability has not been degraded. Note that if an MCS fails an environmental test, then a post-verification thermal performance test is not required.

6.12.1 Vibration. The effect of vibration on an MCS can result in components becoming disconnected or loose, potentially resulting in the loss of system functionality. Items worn or carried on the body are effectively protected from a harsh vibration environment, since the human body is highly damped. Therefore, the most significant vibration to which an MCS will be exposed is during its transportation/handling.

6.12.1.1 Vibration Verification. Report test results from vibration testing conducted in accordance with MIL-STD-810G, *Environmental Engineering Considerations and Laboratory Tests* [9], Method 514.6, Procedure I, General Vibration.

6.12.1.2 Vibration Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including loose parts, assemblies, and/or moving parts that have become separated from the MCS, i.e., material cracks
- Results from thermal performance testing (see Section 6.1) after exposure to Vibration testing

See MCS data sheet in Appendix B for reporting format.

6.12.2 Mechanical Shock. Evaluate the MCS to ensure its functionality after exposure to occasional shocks associated with transportation and handling in its packaged and unpackaged states.

6.12.2.1 Functional Shock Verification. The Functional Shock assessment evaluates the physical integrity of the MCS in its functional state when subjected to 40 g shocks. Report test results after exposure to functional shocks of 40 g's as defined for ground equipment in Table 516.6-I of MIL-STD-810G [9], Method 516.6, Procedure I, Functional Shock.

6.12.2.2 Transit Drop Verification. The Transit Drop test assesses the MCS packaged for shipping when subjected to shocks associated with normal transportation, as defined by 26 drops (one on each face, corner, and edge) from a height of 48 in, in accordance with MIL-STD-810G [9], Method 516.6, Procedure IV.

6.12.2.3 Mechanical Shock Reporting. Test data reporting shall include the following:

- Name of test facility

- Date of testing
- Test data from test facility, which should cite any test failures, including loose parts, structural deficiencies/deformities, assemblies, and moving parts that have become separated from the MCS
- Results from thermal performance testing (see Section 6.1) after exposure to Mechanical Shock testing

See MCS data sheet in Appendix B for reporting format.

6.12.3 High/Low Temperature Storage. An MCS must be fully functional after exposure to storage in high and low temperature environments for significant periods of time. Fluctuating temperature profiles, as well as relatively constant extreme temperature exposures, can significantly affect item functionality, including, but not limited to, expansion/contraction of materials, drying/embrittlement of o-rings and seals, material leaching from packaging, and material integrity.

6.12.3.1 High Temperature Storage Verification. Expose the MCS to transportation and storage temperatures up to 160 °F in accordance with MIL-STD-810G [9], Method 501.5, Procedure I.

6.12.3.2 Low Temperature Storage Verification. Expose the MCS to transportation and storage temperatures to -65 °F in accordance with MIL-STD-810G [9], Method 502.5, Procedure I.

6.12.3.3 High/Low Temperature Storage Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including material degradation, loss of material ductility, and reduced system functionality
- Results from thermal performance testing (see Section 6.1) after exposure to High/Low Temperature Storage testing

See MCS data sheet in Appendix B for reporting format.

6.12.4 Blowing Sand and Dust. MCS functionality may be significantly affected by exposure to blowing sand and dust. Technologies/systems that use a heat exchanger to transfer waste heat to the ambient environment (e.g., condenser) or systems that have components with moving parts (e.g., compressor, fan, pump) may be significantly affected by operating in a sandy/dusty environment. Heat exchangers may clog, reducing their effectiveness. Bearings in motors can become contaminated, potentially rendering them non-functional.

6.12.4.1 Blowing Sand Verification. Expose the MCS to blowing sand particle concentrations of 1.1±0.3 g/m^3 for 8 h in accordance with MIL-STD-810G [9], Method 510.5, Procedure I.

6.12.4.2 Blowing Dust Verification. Expose the MCS to blowing dust particle concentrations of 10±7 g/m^3 for 8 h in accordance with MIL-STD-810G [9], Method 510.5, Procedure II.

6.12.4.3 Blowing Sand and Dust Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including damaged components, clogged orifices and spaces leading to degraded functionality, and material degradation
- Results from thermal performance testing (see Section 6.1) after exposure to Blowing Sand and Dust testing

See MCS data sheet in Appendix B for reporting format.

6.12.5 Salt Fog. Exposure to salt fog can be detrimental to the short-term and long-term functionality of an MCS. Repeated exposure to salt, which is common in coastal regions, can have a significant negative impact on MCS functionality/longevity.

6.12.5.1 Salt Fog Verification. Evaluate the MCS against salt fog concentrations of 5% NaCl in accordance with MIL-STD-810G [9], Method 509.5 for a minimum of two cycles, consisting of a 24-h exposure to the salt fog environment followed by a 24-h dry time.

6.12.5.2 Salt Fog Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including material pitting and corrosion

- Results from thermal performance testing (see Section 6.1) after exposure to Salt Fog testing

See MCS data sheet in Appendix B for reporting format.

6.12.6 Rain. Rain exposure can significantly degrade the functionality of some MCSs, particularly active systems that use motors and require the use of a power source (e.g., battery). Properly protect compartments housing these components to resist water penetration during operation and storage.

6.12.6.1 Rain Verification. Subject the MCS to rain and blowing rain, simulating the effects of operating outdoors unprotected in accordance with MIL-STD-810G [9], Method 506.5, Procedure I.

6.12.6.2 Rain Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including water infiltration through seals
- Results from thermal performance testing (see Section 6.1) after exposure to Rain testing

See MCS data sheet in Appendix B for reporting format.

6.12.7 Humidity. The long-term performance and functionality of MCS can be compromised due to the continual presence of moisture as a result of condensation from use in humid environments. Note that it is not the intent of the humidity metric to measure MCS thermal performance in a humid environment. Rather, the intent is focused on the long-term impacts of operating/storing an MCS in moist environments.

6.12.7.1 Humidity Verification. Expose the MCS to a humid environment in accordance with MIL-STD-810G [9], Method 507.5 for 10 cycles.

6.12.7.2 Humidity Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including degraded system performance due to moisture infiltration
- Results from thermal performance testing (see Section 6.1) after exposure to Humidity testing

See MCS data sheet in Appendix B for reporting format.

6.12.8 Explosive Atmosphere. Due to the nature of many Emergency Responder missions, equipment that may be a source of ignition cannot be used. The intent of this testing is to determine the extent to which an MCS will ignite a fuel-air mixture.

6.12.8.1 Explosive Atmosphere Verification. While operating, expose the MCS to an explosive gaseous-air environment during normal operation in accordance with MIL-STD-810G [9], Method 511.5, Procedure I.

6.12.8.2 Explosive Atmosphere Reporting. Test data reporting shall include the following:

- Name of test facility
- Date of testing
- Test data from test facility, which should cite any test failures, including whether the MCS caused the ignition of the test fuel
- Results from thermal performance testing (see Section 6.1) after exposure to Explosive Atmosphere testing

See MCS data sheet in Appendix B for reporting format.

6.12.9 Electromagnetic Interference (EMI). EMI is any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics/electrical equipment. The radiated emissions from the MCS shall not exceed the limits as specified in MIL-STD-461F (RE102) [10]. The MCS shall remain within the electromagnetic emissions limits specified in Figure RE102-4 (US Army ground limit, 2 MHz to 18 GHz) in MIL-STD-461F [10].

6.12.9.1 EMI Verification. Follow the test procedure, as specified in MIL-STD-461F [10], RE102 (US Army ground limit, 2 MHz to 18 GHz).

6.12.9.2 EMI Reporting. Test data reporting shall include the following:

- Name of test facility

- Date of testing
- Test data from test facility, which should cite any test failures, including the frequency(ies) where power levels exceed the limits (US Army ground limit, 2 MHz to 18 GHz), as specified in Figure RE102-4 in MIL-STD-461F [10].

See MCS data sheet in Appendix B for reporting format.

7. References

1. OSHA Fact Sheet, *Personal Protective Equipment;* www.osha.gov.

2. ASTM F2371-05, *Standard Test Method for Measuring the Heat Removal Rate of Personal Cooling Systems Using a Sweating Heated Manikin*, 2005.

3. National Institute for Occupational Safety and Health, *Criteria for a Recommended Standard: Occupational Noise Exposure;* http://www.cdc.gov/niosh/docs/98-126/chap1.html.

4. ANSI S1-1-1986, *Specifications for Octave –Band and Fractional-Octave-Band Analog and Digital Filters*, 1993, (ASA 65-1986).

5. OSHA Safety and Health Topics, *Permissable Exposure Limits;* http://www.osha.gov/SLTC/pel/.

6. NATICK/TR-89/044, *Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics*, 1988.

7. ASTM F1291-05, *Standard Test Method for Measuring the Thermal Insulation of Clothing Using a Heated Manikin*, 2005.

8. ASTM F2370-05, *Standard Test Method for Measuring the Evaporative Resistance of Clothing Using a Sweating Manikin*, 2005.

9. MIL-STD-810G, *Environmental Engineering Considerations and Laboratory Tests*, 31 October 2008.

10. MIL-STD-461F, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*, 2007.

This document reports research undertaken at the U.S. Army Natick Soldier Research, Development and Engineering Center, Natick, MA, and has been assigned No. NATICK/TR- 12/012 in a series of reports approved for publication.

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Appendix A

Microclimate Cooling System Standard Addendum: Specific Parameters for Designated User Groups

This addendum provides guidance on the MCS parameters that should be validated, cooling rate recommendations, and specific criteria for acoustic detection modeling specifically for designated user groups. The U.S. Customs and Border Protection (CBP) is currently the only user group for which these specific parameters have been defined. As other user groups are identified and defined, they will be added, beginning with Section A.2.

A.1. CBP

A.1.1 Parameter Verification. Table A-1 lists the parameters defined in the MCS Standard and provides guidance on those that require verification, based upon system classification (see Section 4 of the Core Document); definitions are repeated here for reference:

A.1.1.1 Type I. A Type I MCS has all of the following characteristics when in use:

- No moving parts
- Does not require an electrical or fuel based power source
- Worn completely under PPE

A.1.1.2 Type II. A Type II MCS has one or more of the following characteristics when in use:

- Moving parts
- Use of an electrical or fuel based power source
- Partially worn external to PPE

Table A-1 MCS Parameters for CBP

Section	Metric	Type I*	Type II*
5	Markings	x	x
6.1	Thermal Performance	x	x
6.2	Weight	x	x
6.3	Volume/Bulk/Dimensions		
6.3.1	System Dimensions		x
6.3.2	System Bulk	x	x
6.4	Noise		x
6.5	Controls	x	x
6.6	Energy Source		x
6.7	Support Equipment	x	x
6.8	PPE Integration	x	x
6.9	MCS Safety and Health Hazards	x	x
6.10	Human Factors Engineering		
6.10.1	Quick Release		x
6.10.2	Sizing	x	x
6.11	Launderability	x	x
6.12	Environmental Performance		
6.12.1	Vibration	x	x
6.12.2	Mechanical Shock	x	x
6.12.3	High/Low Temperature Storage	x	x
6.12.4	Blowing Sand/Dust		x
6.12.5	Salt Fog		x
6.12.6	Rain		x
6.12.7	Humidity	x	x
6.12.8	Explosive Atmosphere	x	x
6.12.9	Electromagnetic Interference (EMI)		x

*An "x" indicates the parameters that must be validated in accordance with the guidance in Appendix B.

A.1.2. MCS Thermal Performance. The performance of an MCS must take into account environmental and metabolic heat loads, as well as the heat storage characteristics of PPE. For the purposes of this standard, three CBP PPE configurations were identified. They are listed for CBP in Table A-2. In addition to the components listed in Table A-2, each configuration includes underwear, a duty uniform, ballistic helmet, and, boots.

Table A-2 CBP PPE Configurations

Configuration	Components	Total Configuration Weight – kg (lbs)
Ballistic Vest	Body armor with steel plates (NIJ level 3A)	16.3 (35.9)
Belt and Carrier	Low visibility plate carrier (no plates)	8.7 (19.2)
	Patrol belt	
Chest Harness	Chest harness	6.8 (15.0)

Table A-3 provides guidance on recommended MCS cooling rates as a function of PPE configuration and CBP outpost location. To use this table, select the row that corresponds to your outpost location and the column that represents your PPE configuration. The number at the intersection of that row/column is the recommended cooling rate (watts). This value should be compared to the performance data provided by the vendor in the MCS standard data sheet (see Appendix B).

Table A-3 Recommended Cooling Rates (Watts)

CBP Outpost Location	Ballistic Vest	Belt and Carrier	Chest Harness
El Centro, CA	161	255	154
Havre, MT	52	115	7
Spokane, WA	52	115	7
Yuma, AZ	214	250	188
Tucson, AZ	181	246	141
Blaine, WA	0	54	0
El Paso, TX	155	214	117
Marfa, TX	122	172	78
Houlton, ME	50	76	10
Grand Forks, ND	64	119	30
Swanton, VT	64	119	30
Detroit, MI	101	150	68
Buffalo, NY	40	92	3
San Diego, CA (coast)	69	125	36
Del Rio City, TX	253	234	204
New Orleans, LA	254	191	231
Laredo, TX	318	334	280
Rio Grande, TX	318	334	280
Miami, FL	254	191	231

Note — These data represent general recommendations for mitigating heat strain. Individual physiological differences, integration of the MCS with PPE, and other factors will influence the effectiveness of any MCS.

A.1.3 Acoustic Model Data Inputs. To assess the acoustic detectability range of an MCS, testing shall be conducted in accordance with Section 6.4.2.1 of the Core Document. To complete the detectability analysis, use the Army Research Laboratory's (ARL) Human Research an Engineering Directorate (HRED) Auditory Detection Model, as specified in Section 6.4.2.2 with the following data inputs:

- 95 °F/55% relative humidity environment
- Moderately windy conditions
- Sandy desert terrain
- An individual with normal hearing (0-20 dB hearing levels at octave intervals from 250-8000 Hz)

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Appendix B

Microclimate Cooling System Standard Data Sheet

Product Name ____________________
Product Model # ____________________
Type (I or II, see Section 4) __________
Product Description ____________________
____
____
____
____

Company Name ________________________________
Address ________________________________
____
____
Phone ____________________
Fax ____________________
E-mail ________________________________
Website ________________________________

Parameter (Section #)	*Information and Data*
Thermal Performance (6.1)	Test Facility ________________________________ Test Date ________________________________ PPE Configuration[1] ________________________________ ________________________________ ________________________________ ________________________________ ________________________________ Net Heat Removal ____________ watts Duration ____________ minutes If Consumable(s) were replaced/recharged during testing, report the additional duration of heat removal provided (cooling rate must be at least 50 watts above the baseline): Consumable(s) Duration 1. ________________________ ________ minutes 2. ________________________ ________ minutes 3. ________________________ ________ minutes 4. ________________________ ________ minutes Provide a summary of the analysis to demonstrate the extent to which MCS performance is independent of system orientation: ________________________________ ________________________________ ________________________________ ________________________________ ________________________________ ________________________________ ________________________________ ________________________________
Weight (6.2)/System Weight (6.2.1)	System Weight ____________ pounds

[1]List PPE layers from innermost layer to outermost layer tested.

Parameter (Section #)	*Information and Data*
Weight (6.2)/Consumable Weight (6.2.2)	Consumable / Weight 1. ______ ______ pounds 2. ______ ______ pounds 3. ______ ______ pounds 4. ______ ______ pounds
Volume (6.3)/System Dimensions (6.3.1)[2]	System/Component / Length / Width / Depth / Volume 1. ______ ___ in ___ in ___ in ___ in^3 2. ______ ___ in ___ in ___ in ___ in^3 3. ______ ___ in ___ in ___ in ___ in^3 4. ______ ___ in ___ in ___ in ___ in^3
Volume (6.3)/System Bulk (6.3.2)[3]	System/Component / Body Surface Area Covered / Depth 1. ______ ______ ___ in 2. ______ ______ ___ in 3. ______ ______ ___ in
Noise (6.4)/Hearing Loss Prevention (6.4.1)	Exposure Level ______ dBA
Noise (6.4)/Aural Non-detectability (6.4.2)	Range at which MCS is detected ______ Feet Frequency at which MCS is detected ______ Hz
Controls (6.5)	Check the most accurate description of the MCS controls: N/A ☐ On/Off +Incremental Controls ☐ On/Off ☐ Other (please describe) ☐ ______ ______
Energy Source (6.6)	Enter the relevant information on the MCS Energy Source(s) used in the operation of the MCS. If no energy source is used check "N/A": N/A ☐
	Battery — Configuration (e.g., "D-size") / Chemistry (e.g., alkaline, Li-Ion) / Quantity (number used) ______ ______ ______ ______ ______ ______
	Fuel — Type (e.g., JP8, propane) / Amount (ounces) ______ ______

[2] Report data on system and/or components for which dimensions are easily measured.
[3] Report data/information on system and/or components that are worn under PPE and for which dimensions are not easily measured.

Parameter (Section #)	*Information and Data*
Energy Source (6.6)	Other Description: ______ ______ ______
Support Equipment (6.7)	List all support equipment needed to recharge or store consumables. 1. ______ 2. ______ 3. ______ 4. ______
PPE Integration (6.8)	Attach any test data that demonstrates that the fit and functionality of specific PPE has not been compromised when worn or used in conjunction with the MCS. Summarize the test data/analysis in this space; if applicable, reference the test standard against which the MCS and PPE was evaluated. If no testing or analysis has been done, circle "NONE." NONE
	PPE: ______ Test Results Summary: ______ ______ ______ Test Standard (if applicable): ______
	PPE: ______ Test Results Summary: ______ ______ ______ Test Standard (if applicable): ______
	PPE: ______ Test Results Summary: ______ ______ ______ Test Standard (if applicable): ______

Parameter (Section #)	*Information and Data*
MCS Safety and Health Hazards (6.9)	List the MCS components for which an MSDS has been submitted: 1. ________ 2. ________ 3. ________ 4. ________ 5. ________
Human Factors Engineering (6.10)/Quick Release (6.10.1)	Enter Connector description(s), if applicable: 1. ________ 2. ________ 3. ________ Average Break Force: ________ lbf
	Enter the PPE designations (see Appendix A) below for each MCS (external components of Type II only) emergency doff evaluation conducted: PPE Designation (see Appendix A) — Avg MCS Doff Time 1. ________ ________ s 2. ________ ________ s 3. ________ ________ s 4. ________ ________ s 5. ________ ________ s
Human Factors Engineering (6.10)/Sizing (6.10.2)	Enter MCS sizing information (garment component only): Size (e.g. Small) — Body Area Parameter (e.g. chest circumference) — Dimensional Range (e.g., 31 – 34) ____ ________ ____ in ____ ________ ____ in ____ ________ ____ in ____ ________ ____ in ____ ________ ____ in ____ ________ ____ in ____ ________ ____ in
Launderability (6.11)	Enter a short description of the laundry procedure(s) for each MCS textile component (where appropriate, cite the applicable laundry test standard): Item — Laundry Procedure/Standard 1. ________ ________ ________ ________ 2. ________ ________ ________ ________ 3. ________ ________

<table>
<tr><th colspan="2">Environmental Performance (6.12)</th></tr>
<tr><td>Parameter (Section #)</td><td>Information and Data</td></tr>
<tr><td rowspan="2">Vibration (6.12.1)</td><td>Test Facility ____
Test Date ____
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____</td></tr>
<tr><td>Results of thermal performance testing (post Vibration testing):
Net Heat Removal ____ watts
Duration ____ minutes</td></tr>
<tr><td rowspan="2">Mechanical Shock (6.12.2)/ Functional Shock (6.12.2.1)</td><td>Test Facility ____
Test Date ____
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____</td></tr>
<tr><td>Results of thermal performance testing (post Functional Shock testing):
Net Heat Removal ____ watts
Duration ____ minutes</td></tr>
<tr><td rowspan="2">Mechanical Shock (6.12.2)/ Transit Drop (6.12.2.2)</td><td>Test Facility ____
Test Date ____
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____</td></tr>
<tr><td>Results of thermal performance testing (post Transit Drop testing):
Net Heat Removal ____ watts
Duration ____ minutes</td></tr>
</table>

<table>
<tr><th colspan="2">Environmental Performance (6.12) [continued]</th></tr>
<tr><td>Parameter (Section #)</td><td>Information and Data</td></tr>
<tr><td rowspan="2">High/Low Temperature Storage (6.12.3)/High Temperature Storage (6.12.3.1)</td><td>Test Facility ____________________
Test Date ____________
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____________________</td></tr>
<tr><td>Results of thermal performance testing (post High Temperature Storage testing):
Net Heat Removal __________ Watts
Duration __________ Minutes</td></tr>
<tr><td rowspan="2">High/Low Temperature Storage (6.12.3)/Low Temperature Storage (6.12.3.2)</td><td>Test Facility ____________________
Test Date ____________
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____________________</td></tr>
<tr><td>Results of thermal performance testing (post Low Temperature Storage testing):
Net Heat Removal __________ watts
Duration __________ minutes</td></tr>
<tr><td rowspan="2">Blowing Sand and Dust (6.12.4)/Blowing Sand (6.12.4.1)</td><td>Test Facility ____________________
Test Date ____________
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____________________</td></tr>
<tr><td>Results of thermal performance testing (post Blowing Sand testing):
Net Heat Removal __________ watts
Duration __________ minutes</td></tr>
</table>

Environmental Performance (6.12) [continued]	
Parameter (Section #)	*Information and Data*
Blowing Sand and Dust (6.12.4)/Blowing Dust (6.12.4.2)	Test Facility __________ Test Date __________ Test Results (circle one) Pass Fail If Fail, please describe failure: __________ __________ __________
	Results of thermal performance testing (post Blowing Dust testing): Net Heat Removal __________ watts Duration __________ minutes
Salt Fog (6.12.5)	Test Facility __________ Test Date __________ Test Results (circle one) Pass Fail If Fail, please describe failure: __________ __________ __________
	Results of thermal performance testing (post Salt Fog testing): Net Heat Removal __________ watts Duration __________ minutes
Rain (6.12.6)	Test Facility __________ Test Date __________ Test Results (circle one) Pass Fail If Fail, please describe failure: __________ __________ __________
	Results of thermal performance testing (post Rain testing): Net Heat Removal __________ watts Duration __________ minutes

<table>
<tr><th colspan="2">Environmental Performance (6.12) [continued]</th></tr>
<tr><td>Parameter (Section #)</td><td>Information and Data</td></tr>
<tr><td rowspan="2">Humidity (6.12.7)</td><td>Test Facility ________________________________
Test Date ________________
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
________________________________</td></tr>
<tr><td>Results of thermal performance testing (post Humidity testing):

Net Heat Removal ____________ watts
Duration ____________ minutes</td></tr>
<tr><td rowspan="2">Explosive Atmosphere (6.12.8)</td><td>Test Facility ________________________________
Test Date ________________
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
________________________________</td></tr>
<tr><td>Results of thermal performance testing (post Explosive Atmosphere testing):

Net Heat Removal ____________ watts
Duration ____________ minutes</td></tr>
<tr><td>Electromagnetic Interference (6.12.9)</td><td>Test Facility ________________________________
Test Date ________________
Test Results (circle one) Pass Fail
If Fail, please describe failure:
____
____
____

Note: Provide plot of MCS scan (Limit Level (dBμV/m) vs. Frequency (Hz)) at frequencies 2 MHz-18 GHz, with a comparison to the U.S. Army limit (see Figure RE102-4, MIL-STD-461F).</td></tr>
</table>